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The Influence of Multiple Trials and Computer-mediated Communication on  
Collaborative and Individual Semantic Recall

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## Abstract

Collaborative inhibition is a phenomenon where collaborating groups experience a decrement in recall when interacting with others. Despite this, collaboration has been found to improve subsequent individual recall. We explore these effects in semantic recall, which is seldom studied in collaborative retrieval. We also examine “parallel CMC”, a synchronous form of computer-mediated communication that has previously been found to improve collaborative recall [Hinds, J. M., & Payne, S. J. (2016).

Collaborative inhibition and semantic recall: Improving collaboration through computer-mediated communication. *Applied Cognitive Psychology*, 30(4), 554-565]. Sixty-three triads completed a semantic recall task, which involved generating words beginning with “PO” or “HE” across three recall trials, in one of three retrieval conditions: Individual - Individual - Individual (III), Face-to-face - Face-to-Face - Individual (FFI) and Parallel - Parallel - Individual (PPI). Collaborative inhibition was present across both collaborative conditions. Individual recall in Recall 3 was higher when participants had previously collaborated in comparison to recalling three times individually. There was no difference between face-to-face and parallel CMC recall, however subsidiary analyses of instance repetitions and subjective organisation highlighted differences in group members’ approaches to recall in terms of organisation and attention to others’ contributions. We discuss the implications of these findings in relation to retrieval strategy disruption.

*Keywords:* collaborative inhibition, semantic recall, computer mediated communication, retrieval strategy disruption

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## The Influence of Multiple Trials and Computer-mediated Communication on Collaborative and Individual Semantic Recall

Collaboratively recalling information is an activity that underpins many tasks in organisational and social settings, when solving problems, making decisions and reminiscing about past events. Intuitively, there might be advantages of collaboration – because of the efforts of multiple minds and the possibility of cross-cueing. However, the well-established literature on collaborative inhibition has reported that collaboration can often be detrimental (e.g. Andersson & Ronnberg, 1995; Basden, Basden & Henry, 2000; Weldon & Bellinger, 1997; Wright & Klumpp, 2004), collaborating individuals are believed to experience a disruption to their retrieval strategy (Basden, Basden, Bryner & Thomas, 1997), hindering their ability to recall. These effects have been widely demonstrated in episodic recall, and more recently in semantic recall (Hinds & Payne, 2016). However, despite a disruption, recent research has found that collaboration can benefit subsequent individual episodic recall, (e.g. Barber & Rajaram, 2011; Blumen & Rajaram, 2008; Choi, Blumen, Congleton & Rajaram, 2014; Congleton & Rajaram, 2011).

This article aims to contribute to and extend the existing work on collaborative inhibition by answering three questions: (1) is semantic recall susceptible to collaborative inhibition? (2) can computer-mediated communication (CMC) improve collaborative recall? and (3) does prior collaboration face-to-face or via CMC improve subsequent individual semantic recall?

### **Collaborative inhibition and retrieval strategy disruption**

Collaborative inhibition is the finding that collaborating groups experience a decrement in their recall, which is evident when comparing their performance to nominal groups (the pooled, non-redundant contributions from non-interacting group

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members) (e.g. Andersson & Ronnberg, 1996; Basden et al., 1997; Weldon & Bellinger, 1997). The dominant hypothesis concerning the underlying cause of collaborative inhibition is retrieval strategy disruption, which posits that each individual has their own idiosyncratic organisation, (e.g., preferred order of retrieval) which is disrupted through exposure to each others' recall output (Basden et al., 1997; Finlay, Hitch & Meudell, 2000; Wright & Klumpp, 2004).

To date, much of the evidence of retrieval strategy disruption is provided by studies of episodic recall. Episodic recall is considered to be particularly vulnerable to disruption, given that episodic memory is volatile and comprises information that is particular to the time and place of encoding (Andersson & Ronnberg, 1996). In contrast, semantic recall – overlearned information and general knowledge stored in long-term memory (Tulving, 1983) is often supposed to be robust and as such has received far less attention in research on collaborative inhibition. Weldon (2000) found some evidence of collaborative inhibition in tasks that involved recalling US states and reconstructing maps and figures, whereas collaborative facilitation was evident when groups answered general knowledge questions. However these results can only be classed as preliminary, given that the tasks were distractor tasks that formed part of another experiment. Andersson and Ronnberg (1996) also found collaborative facilitation when groups answered history questions.

In a recent study by Hinds and Payne (2016), collaborative inhibition was demonstrated in two semantic recall tasks, one where groups generated words beginning with predetermined digraphs (e.g. *BR*, *HE*) and another where groups constructed words from a set of designated letters (a 'Scrabble' task). Hinds and Payne's thesis was that whilst semantic memory is more robust than episodic memory, it is still subject to failure – people can forget well-known information for a

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whole variety of reasons, perhaps they do not recall certain information frequently or distraction causes them to forget. Hinds and Payne (2016) argued that semantic recall can often resemble brainstorming style tasks, and indeed brainstorming requires retrieval from semantic memory (Nijstad & Stroebe, 2006). Collaborative brainstorming is a similar yet distinct area of research from collaborative recall, yet equivalent inhibitory effects are widely demonstrated (e.g. Diehl & Stroebe, 1987, 1991).<sup>1</sup> Essentially, brainstorming requires recalling from semantic memory and indeed a number of tasks used in brainstorming studies, could arguably be classed as semantic recall tasks if framed as such, for example, Bouchard's (1972) brainstorming task was 'uses of an old tyre' (Hinds & Payne, 2016). It seems likely that people may view a brainstorming task differently from a recall task, but it seems unlikely that instruction to recall rather than brainstorm would protect output from interference. In attempt to further investigate the potential for collaborative inhibition in semantic recall, we seek to replicate these findings and therefore predict that collaborating groups will experience inhibition.

### **Computer-mediated communication**

Computer mediated communication (CMC) introduces a number of changes to interactions, which may therefore influence how people communicate information. In comparison to face-to-face interaction, CMC is often slower, non-verbal cues are lost, and output can be reviewed and edited. The physical separation from recipients may increase a person's confidence in communication (Sproull & Kiesler, 1991) or may increase the likelihood for social loafing (Ekeocha & Brennan, 2008). Hinds and Payne (2016) examined 'parallel CMC', a mode of communication where all group

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<sup>1</sup> In brainstorming research, the deficit is referred to as the 'nominal group effect' rather than collaborative inhibition and rather than retrieval strategy disruption.

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members could communicate simultaneously (e.g. chatrooms, or instant messaging), and found that parallel CMC semantic recall was significantly higher than face-to-face recall. Hinds and Payne (2016) argued this occurred due to the fact that CMC can relieve some of the inhibition endured in face-to-face interaction; CMC removes enforced turn-taking, enabling all group members to contribute simultaneously, which may allow for personal retrieval strategy usage. Further, CMC opens up the possibility of examining group member's attention levels during collaboration. Hinds and Payne (2016) argued that CMC allowed group members to 'partially attend' to each other's contributions, that is, they were not forced to listen and could sometimes ignore other's contributions, which may allow them to utilise personal retrieval strategies. We therefore predict that parallel CMC groups will recall more than face-to-face groups across both recall trials, (but fewer items than nominal groups).

### **Collaborative inhibition and subsequent individual recall**

Although collaborating groups typically experience inhibition in recall, numerous studies have demonstrated that inhibition appears to be temporary as items seemingly lost in collaborative recall subsequently appear in individual recall (Barthel, Wessel, Rafaele, Huntjens & Verwoerd, 2016; Basden et al., 2000; Blumen & Rajaram, 2008; Blumen & Stern, 2011; Congleton & Rajaram, 2011; Harris et al., 2013; Henkel & Rajaram, 2011; Marion & Thorley, 2016; Weldon & Bellinger, 1997). Further, prior collaboration has also been found to improve subsequent individual recall, relative to earlier individual recall. This has been reliably demonstrated across a variety of conditions in episodic recall: when delays are varied between recall trials (Blumen, Young & Rajaram, 2014; Congleton & Rajaram, 2011), with a week's delay between trials (Blumen & Stern, 2011) and when recall is conducted with different groups of people (Choi et al., 2014). There are a number of

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explanations for these results. First, individual recall following collaboration enables individuals to return to their preferred retrieval strategy, thus items previously lost through disruption may reappear (Blumen & Rajaram, 2008). Second, collaboration re-exposes individuals to items, providing a second learning/encoding opportunity therefore strengthening the items in memory (Blumen & Rajaram, 2008). Third, multiple collaborative recall trials expose individuals to additional stimuli more than once, providing further opportunity to learn/encode additional items (Blumen & Rajaram, 2008). Given that collaborative inhibition can seemingly disrupt semantic recall, we examine, in this article, whether similar effects also extend to subsequent individual semantic recall. Therefore, we predict that prior collaboration will increase subsequent individual recall.

### **Subsidiary analyses**

Our experimental design provides an opportunity to analyse the data in numerous different ways, which may help to provide additional insights with regards to the mechanisms underlying collaborative inhibition and whether these mechanisms change over time or differ when transitioning from group to individual recall. Further, the parallel CMC condition allows us to capture the contributions of each group member so that we can assess whether individual approaches towards recall differ in a group context. In addition to our main analyses, we perform a series of subsidiary analyses, which can be briefly summarised as follows:

- **Hypermnesia** – Hypermnesia is an effect where repeated trials result in an increase in recall (Payne, 1987; Weldon & Bellinger, 1997; Wheeler & Roediger, 1992). It has already been demonstrated in individual semantic recall (e.g. Brown, 1923; Payne, 1986; Roediger, Payne, Gillespe & Lean, 1982), thus we expect to see similar findings in collaborative recall.
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- Instance repetitions – Nominal groups should generate numerous instance repetitions, and face-to-face groups should generate very few as they filter duplications out. Hinds and Payne (2016) found that parallel CMC groups generated significantly fewer instance repetitions than nominal groups, but more than face-to-face groups, suggesting that parallel CMC group members pay less attention to each others' contributions. We therefore expect to replicate these findings here.
- Clustering – Clustering is a measure that assesses how individuals and groups organise recall. It is typically reported in studies of episodic recall where groups recall from categorised word lists (e.g. Basden et al. 1997; Finlay et al. 2000). Findings demonstrate that groups often organise their recall differently to individuals, and this 'disruption' to ones' preferred order of recall can therefore be used to supplement explanations of retrieval strategy disruption. We argue that equivalent clustering measures can be applied to semantic recall to assess retrieval strategy disruption in a similar way. Thus we anticipate that groups will organise recall differently to individuals.

In order to aid reading, we have applied a particular notation which we use to refer to the different experimental conditions. This notation is commonly used in similar studies of collaborative retrieval and is structured as follows – each recall trial (one, two, or three) is denoted by a letter (I = Individual, N= Nominal, F = Face-to-face and P = Parallel CMC), which represents the corresponding recall condition. For instance, NNI indicates that the first two recall trials were conducted by nominal groups and the third trial was individual recall. Further, we also use bold, underlined notation when

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discussing a particular recall trial, such that NNI is used when discussing the first, nominal-group recall trial of this condition.

## **Method**

### **Participants**

One hundred and eighty-nine students and staff from the University of Manchester/University of Bath volunteered to take part in the study. The mean age was 25.10 years (65 males, 124 females). Participants were recruited through an advertisement placed on the university website. The incentive for participation was £5 per participant.

### **Design**

The between-subjects factor was the type of retrieval sequence (NNI vs. FFI vs. PPI). Triads were scheduled to arrive at the lab at the same time, with no regard to gender. If all three participants showed up, they were automatically assigned to the face-to-face condition (until 10 trials had been executed). If one or two participants showed up, they were assigned to the nominal condition, thus the nominal condition ran with either one, two or three participants working simultaneously. There were 10 triads in the nominal and face-to-face conditions and 12 triads in the parallel CMC condition. Each condition was set up as follows:

- Nominal (NNI) – Each participant was allocated to a private computer in a different corner of the room, so that all group members sat with their backs facing one another. There was a distance of approximately 5 m between each participant. They were informed that they would be working alone for the duration of the experiment. Thus, they were not aware that their recalled items would later be pooled to form a nominal group contribution.
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- Face-to-face (FFI) – One participant was asked to serve as the typist for the duration of the two collaborative recall trials. Participants were seated round one computer and the typist sat in the middle. For the individual recall trial (Recall 3), the typist remained at the computer and the other two participants were allocated to private computers as per the configuration for the nominal condition.
- Parallel CMC (PPI) – The same seating configuration as that for nominal groups was applied. Participants were informed that they would all be present in the same session, meaning that their contributions would be visible to all group members and identifiable to the group by their designated experimental ID.

### **Materials and Apparatus**

**Software.** The participants used either Windows Live Messenger version 8.5.1302 (<http://download.live.com/messenger>) or Google Hangouts to record their answers. Both are a type of chat software that permit one-to-one and group chat. Contributions are not anonymous as each user has an ID and users type their contributions and publish them to the conversation thread upon pressing *Enter*. A number of accounts were opened for the study. An account was also created for the experimenter in order to monitor and initiate all conversations and so that participants had a recipient to send messages to. The size of conversation windows were maximised throughout the experiment so that participants could see the maximum number of previous contributions possible throughout the recall trial. The chat sessions scrolled down automatically when the window became full. The screen became full when 29 items were listed. Participants in the same conversation in the

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parallel CMC condition were able to scroll up and down without affecting the views of the other participants' conversation windows.

**Semantic task.** We used two orthographic digraphs *PO*, and *HE*, similar to Hinds and Payne (2016). The reasons for using this type of semantic retrieval stimuli were twofold; first, orthographic categories are unavoidably used on a daily basis in language processing, and whilst some people will have larger vocabularies than others, everyone should have a relatively large number of items stored. Second, the generative aspect of the task offers the opportunity for words to stimulate the retrieval of similar or related words, for instance *pot* may provoke the items *pots*, *potted*, *potential* and so forth. This enables us to explore the potential for cross-cueing if group members are able to utilize each others recall to prompt additional items, or retrieval strategy disruption if group members focus on generating similar words and subsequently forget their other contributions.

### **Procedure**

At the start of the experiment, participants were shown how to use the chat software. Participants were instructed to work individually/together to recall as many words as possible beginning with either *PO* or *HE*, that is, participants generated words using only one digraph. Then, the experimenter (first author) initiated the conversation by sending a message to the participant/s who were instructed to reply by sending each recalled item one at a time. The participants were informed that each recall trial would last for 8 minutes and the stopwatch (visible on the screen or screens) was started when the experimenter pressed '*Enter*' upon sending the first message. The experimenter monitored all conversations, but made no contribution.

Participants in the collaborative conditions received no instruction as to whether they had to agree on answers before adding them to the recall list. Further,

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no instructions were provided on how to resolve disagreements. Items that were filtered out verbally and not reported via the chat software were not counted in the final score. After each of the first two recall trials, participants were presented with a distractor task, which involved completing Suduko puzzles for 4 minutes. The puzzles were always completed individually. At the end of the experiment, participants were debriefed and thanked for their participation.

## Results and Discussion

### Scoring

Correct recall scores were computed for each recall trial in each condition (NNI, FFI, PPI). All words that started with *PO* or *HE* and were entries in *Merriam Webster's Collegiate Dictionary* (2005) were scored as correct. Spelling mistakes (following the digraph prompt) as judged by the experimenter (first author) were permitted. Nominal group scores in Recall 1 and Recall 2 were calculated from the combined individual scores and instance repetitions and incorrect items were removed. Hypermnnesia scores were computed by calculating the difference scores between recall trials for each group/individual as appropriate. The alpha was set at  $p < .05$  unless noted otherwise. Table 1 displays the mean scores for correct items, instance repetitions and clustering in Recall 1, Recall 2 and Recall 3.

Before conducting our main analyses, we performed a preliminary analysis to establish whether there was a difference in the number of words generated per digraph prompt, that is, whether overall participants recalled more words beginning with '*PO*' than '*HE*'. This was to reinforce that the main results were not influenced by any difference in the difficulty of generating particular digraphs. A 2 x 3 mixed ANOVA was non-significant,  $F(1,60) = .000$ ,  $p = .992$ ,  $\eta^2 = .000$  across recall 1-2 and across the two digraphs,  $F(1,60) = 1.386$ ,  $p = .244$ ,  $\eta^2 = .022$ . Further, a one-way between

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subjects ANOVA for recall 3 was also non-significant,  $F(1,186) = .000$ ,  $p = .986$ ,  $\eta^2 = .000$ .

### **Correct items (Recall 1 and Recall 2)**

A 2 x 3 mixed ANOVA demonstrated significant main effects across recall 1-2  $F(1,60) = 104.302$ ,  $p < .001$ ,  $\eta^2 = .635$  and across the collaborative conditions  $F(2,60) = 10.490$ ,  $p < .001$ ,  $\eta^2 = .259$ . There was not a significant interaction between condition and recall trial,  $F(2, 60) = .677$ ,  $p = .512$ ,  $\eta^2 = .022$ . Planned comparisons revealed that nominal groups recalled more than collaborating groups in Recall 1 (NNI vs. FFI, PPI),  $p < .001$  and Recall 2 (NNI vs. FFI, PPI),  $p < .001$  however face-to-face and parallel CMC recall were equivalent,  $p = .429$  (Recall 1) and  $p = .207$  (Recall 2).

These findings provide mixed support for our hypotheses (NNI > PPI > FFI and NNI > PPI > FFI). First, our findings replicate Hinds and Payne's (2016) research, where nominal groups outperformed both face-to-face and parallel CMC groups. This therefore provides more evidence for collaborative inhibition in semantic recall. However, parallel CMC did not improve recall relative to face-to-face recall. We are not sure exactly what has caused a discrepancy between these two results. A potential explanation is the difference in experimental design employed across the two studies. Hinds and Payne (2016) (Experiment 1) employed a within-subjects design where semantic recall trials were intermingled with episodic recall trials, thus different digraphs were used in each condition. In that experiment participants completed 6 recall trials (3 episodic, 3 semantic), which provided participants with more experience in recalling each of the conditions. Perhaps it was this experience that strengthened the effects of these conditions.

### **Final individual recall (Recall 3)**

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Our hypothesis that prior collaboration would increase subsequent individual recall when compared to prior individual recall ( $\text{FFI} \text{, PPI} > \text{NNI}$ ), was supported by a one-way between-subjects ANOVA,  $F(2,186) = 5.052, p = 0.007, \eta^2 = .053$ . A planned comparison demonstrated that individuals who previously recalled collaboratively recalled more than individuals who did not ( $\text{FFI} \text{, PPI} > \text{NNI}$ ),  $t(186) = -3.068, p = .002, d = 0.42$ . There was no difference in recall between face-to-face and parallel CMC groups ( $\text{FFI} = \text{PPI}$ ) as a planned comparison was non-significant,  $t(93) = -.832, p = .407, d = -0.15$ .

As expected prior collaboration improved subsequent individual recall. This finding therefore suggests that collaborative inhibition in semantic recall is only temporary as items lost through collaboration re-appear, alongside extra items due to exposure to others' contributions. Further, this finding extends similar work on episodic recall (e.g. Blumen & Rajaram, 2008, 2009; Blumen et al., 2014; Choi et al., 2014; Congleton & Rajaram, 2011). We posit that the reason for this effect is the same for semantic recall as it is in episodic recall – collaborative inhibition disrupts retrieval strategies, then individuals utilise their preferred strategies when recalling in isolation. However, we note that the subsequent improvement in individual recall may differ from episodic recall. In studies of episodic recall, participants are typically exposed to, and encode the same retrieval stimuli at the same time, whereas in this case individuals are likely to have different amounts of semantic knowledge, encoded at different times. It is therefore impossible to determine how much information has been lost or forgotten at recall. Similarly, it is not possible to establish whether collaboration re-exposes group members to information they already knew or exposes them to new information. Thus the final individual recall may be a combination of episodic and semantic recall, rather than purely semantic.

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## Hypermnesia

Table 2 displays the mean hypermnesia scores for Recall 1-2. To test if there were hypermnesia effects, a series of paired t-tests compared Recall 1 with Recall 2. Hypermnesia was present in all tests, namely nominal ( $\underline{\text{NNI}} < \text{N}\underline{\text{NI}}$ ),  $t(20) = -5.912$ ,  $p < .001$ ,  $d = -0.84$ , face-to-face ( $\underline{\text{FFI}} < \text{F}\underline{\text{FI}}$ ),  $t(20) = -6.419$ ,  $p < .001$ ,  $d = -0.75$ , and parallel CMC recall ( $\underline{\text{PPI}} < \text{P}\underline{\text{PI}}$ ),  $t(20) = -5.720$ ,  $p < .001$ ,  $d = -0.74$ .

Tests for hypermnesia in individual recall were also significant in Recall 1-2,  $t(62) = -5.553$ ,  $p < .001$ ,  $d = -0.37$ , and Recall 2-3,  $t(62) = -5.671$ ,  $p < .001$ ,  $d = -0.29$ .

Hypermnesia did not differ between conditions, as a one-way between subjects ANOVA was non-significant,  $F(2,60) = .668$ ,  $p = .517$ ,  $\eta^2 = .022$  (nominal versus face-to-face versus parallel CMC).

As expected, hypermnesia was present in all conditions ( $\underline{\text{NNI}} > \text{N}\underline{\text{NI}}$  and  $\underline{\text{FFI}} > \text{F}\underline{\text{FI}}$  and  $\underline{\text{PPI}} > \text{P}\underline{\text{PI}}$ , and  $\underline{\text{III}} > \text{I}\underline{\text{II}}$  and  $\underline{\text{III}} > \text{II}\underline{\text{I}}$ ). These findings therefore reflect typical findings of hypermnesia in episodic recall (e.g. Blumen & Rajaram, 2008; Meudell et al., 1995; Weldon & Bellinger, 1997) and extend the effect to semantic collaborative retrieval.

## Instance repetitions

The findings supported our hypotheses across both recall trials. In Recall 1, a one-way between-subjects ANOVA demonstrated a significant main effect,  $F(2,60) = 87.907$ ,  $p < .001$ ,  $\eta^2 = .746$ . Planned comparisons demonstrated that nominal groups generated more instance repetitions than collaborating groups, ( $\underline{\text{NNI}} > \text{P}\underline{\text{PI}}$ ,  $\underline{\text{FFI}}$ ),  $t(60) = 13.138$ ,  $p < .001$ ,  $d = -2.75$ , and that parallel groups generated more than face-to-face groups, ( $\underline{\text{PPI}} > \underline{\text{FFI}}$ ),  $t(60) = 4.560$ ,  $p < .001$ ,  $d = 1.87$ .

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In Recall 2, one-way between-subjects ANOVA demonstrated a significant main effect,  $F(2,60) = 59.579$ ,  $p < .001$ ,  $\eta^2 = .665$ . Planned comparisons demonstrated that nominal groups generated more instance repetitions than collaborating groups, ( $\underline{\text{NNI}} > \underline{\text{PPI}}$ ,  $\underline{\text{FFI}}$ ),  $t(60) = 11.085$ ,  $p < .001$ ,  $d = 2.08$  and parallel groups generated more than face-to-face groups ( $\underline{\text{PPI}} > \underline{\text{FFI}}$ ),  $t(60) = 5.593$ ,  $p = .001$ ,  $d = 1.86$ .

These findings replicate Hinds and S. J. Payne's (2016) work, and provide further evidence to suggest that group members partially attended to each others' contributions in parallel CMC collaboration.

**Instance repetitions across trials (over time).** The data in Table 1 clearly demonstrates that the instance repetitions increased from Recall 1 to Recall 2 in each condition. In order to establish whether this increase was in line with hypermnesia effects we performed analyses on the proportion of instance repetitions to total output in each condition. A change in the ratio of instance repetitions to correct items across recall trials would suggest a change in attention level (as opposed to an increase reached through hypermnesia). Paired t-tests demonstrated an increase in the proportion of instance repetition generated in both face-to-face,  $t(20) = -3.368$ ,  $p = .002$ ,  $d = -1.00$ , and parallel CMC recall,  $t(20) = -2.836$ ,  $p = .010$ ,  $d = -0.64$ , however there was no change in nominal group recall,  $t(20) = -.318$ ,  $p = .753$ ,  $d = -0.12$ . Taken together, these findings provide a number of useful insights for collaborative recall. First, the results indicate that instance repetitions in nominal groups increases in line with hypermnesia. Second, in collaborative recall instance repetitions form a larger proportion of the total output in Recall 2 than in Recall 1. Given that face-to-face instance repetitions are still extremely low, (and markedly less than parallel CMC instance repetitions) it therefore seems plausible that face-to-face group members are

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possibly less stringent in tracking and filtering out duplicates on the second recall trial. Further, the increase for parallel CMC groups would suggest that group members attended less to each others' contributions in Recall 2. It may be the case that in both conditions, collaboration in Recall 1 makes individuals more accustomed to their group members/recall conditions, which makes them more inclined to attend less in Recall 2.

### **Clustering**

In line with Hinds and Payne's (2016) analysis of clustering in semantic recall, we applied the Adjusted Ratio of Clustering (ARC) formula to assess the extent to which group members clustered words by spelling. The ARC measure, developed by Roenker, Thompson and Brown (1971) is typically used in episodic recall tasks, where subjects recall categorized words lists, however we adapted the measure by counting the number of successive words with the same third letter following the digraph prompt, for example, post, posted, pose, port, porter was counted as three instances from two categories. The ARC measure calculates an index, where clustering can be at maximum level (the value of the index = 1.00) or clustering can be at chance level (the value of the index = 0). If clustering were at maximum, then participants would have recalled all items category by category, and if clustering were at chance level, then no two items from the same category would have been recalled in succession. As the ARC measure was inapplicable to nominal group scores, clustering measures were taken for individual participants. Clustering scores for face-to-face and parallel CMC groups were calculated in the same way as an individual participant's protocol. Further, clustering scores were also calculated for individuals within the parallel CMC condition and analysed separately. In line with Basden et

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al's (1997) analyses, the occurrence of incorrect items and instance repetitions of items with a sequence was ignored.

In Recall 1, a one-way between-subjects ANOVA demonstrated a significant main effect,  $F(2, 105) = 6.452$ ,  $p = .002$ ,  $\eta^2 = .124$ . A planned comparison revealed no difference in clustering between face-to-face groups and individuals ( $\underline{\text{III}} = \underline{\text{FFI}}$ ),  $t(105) = .734$ ,  $p = .465$ ,  $d = 0.47$ . Clustering was higher for individuals than parallel CMC groups ( $\underline{\text{III}} > \underline{\text{PPI}}$ ),  $t(105) = 3.157$ ,  $p = .002$ ,  $d = 0.67$  and higher for face-to-face groups than parallel CMC groups ( $\underline{\text{FFI}} > \underline{\text{PPI}}$ ),  $t(105) = 3.259$ ,  $p = .002$ ,  $d = 1.70$ .

In Recall 2, our analyses revealed the same pattern of results; a one-way between subjects ANOVA demonstrated a significant main effect,  $F(2, 105) = 17.835$ ,  $p < .001$ ,  $\eta^2 = .282$ . Planned comparisons revealed no difference in clustering between face-to-face groups and individuals ( $\underline{\text{III}} = \underline{\text{FFI}}$ ),  $t(105) = .796$ ,  $p = .796$ ,  $d = -0.15$ . Clustering was higher for individuals than parallel CMC groups ( $\underline{\text{III}} > \underline{\text{PPI}}$ ),  $t(105) = 5.789$ ,  $p < .001$ ,  $d = 1.32$  and for face-to-face groups than parallel CMC groups ( $\underline{\text{FFI}} > \underline{\text{PPI}}$ ),  $t(105) = 4.633$ ,  $p < .001$ ,  $d = -1.95$ . A one-way ANOVA for clustering in Recall 3 was significant,  $F(2, 184) = 1.215$ ,  $p = .299$ ,  $\eta^2 = .014$ , thus suggesting that individuals utilized their personal retrieval strategies.

We conducted t-tests to compare individuals with parallel CMC individuals. Clustering was higher for individuals in both Recall 1,  $t(122) = 2.291$ ,  $p = .024$ ,  $d = 0.49$  and Recall 2,  $t(122) = 5.274$ ,  $p < .001$ ,  $d = -0.83$ . There was no difference in Recall 3,  $t(122) = -1.540$ ,  $p = .126$ ,  $d = -0.16$ .

These findings provide mixed support for our hypotheses in both recall trials. First, contrary to our hypothesis, face-to-face group clustering was not higher than individual clustering (Hinds and Payne (2016) found that clustering for face-to-face recall was higher than individual recall). Hinds and Payne (2016) argued that strategy

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disruption could be identified by a change in organisation, which could be represented by higher or lower clustering scores. So in this instance, we cannot use clustering to help explain retrieval strategy disruption in face-to-face recall, given that clustering for face-to-face groups and individuals was equivalent across both Recall trials.

Clustering for parallel CMC groups was lower than individuals, thus confirming our hypothesis. Further, clustering for parallel CMC individuals was lower than individual clustering across both trials. Taken together, these findings demonstrate that parallel CMC group members do not fully co-ordinate their contributions. However, despite the freedom to contribute simultaneously, there is some influence of collaboration, which disrupts their organisation of recall (when compared with individuals).

### Category exploration

Another measure of organisation is category exploration, that is, the extent to which participants recall from the range of categories available. Hyman, Cardwell and Roy (2013) performed an analysis of category exploration in episodic recall, and our design of categorising word by third letter enabled us to perform a similar analysis. Thus we analysed the number of categories with at least one instance of recall. A 2 x 3 mixed ANOVA demonstrated significant main effects across recall 1-2  $F(1, ) = 11.593, p < .001, \eta^2 = .114$  and across the collaborative conditions  $F(2, 142) = 14.272, p < .001, \eta^2 = .241$ . There was not a significant interaction between condition and recall trial,  $F(2, 142) = 1.535, p = .221, \eta^2 = .033$ . Planned comparisons revealed that collaborating groups recalled more than individuals in Recall 1 (**III** vs. **FFI**, **PPI**),  $p < .001$  and Recall 2 (**III** vs. **FFI**, **PPI**),  $p < .001$  however face-to-face and parallel CMC recall were equivalent,  $p = .094$  (Recall 1) and  $p = .053$  (Recall 2).

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In Recall 3, a one-way between-subjects ANOVA demonstrated a significant main effect,  $F(2,184) = 6.937$ ,  $p = .001$ ,  $\eta^2 = .014$ . Planned comparisons demonstrated that collaborating groups explored more categories than individuals (III vs. FFI, PPI),  $p < .001$ , but there was no difference between face-to-face and parallel CMC groups (FFI vs. PPI),  $p = .304$ . Hyman et al. (2013) found that collaborative inhibition could be explained by reduced category exploration by collaborative groups. One may therefore expect that parallel CMC would allow more exploration than face-to-face collaboration who may be likely to streamline responses and through turn-taking. The fact that this did not happen reflects the overall equivalence in recall between collaborating groups.

### Time

All groups were allowed the same length of time for recall. It is likely that collaborating groups need more time to recall than nominal groups because collaborating group members spend time taking turns and reading each others' contributions. Therefore, it is possible that lower collaborative recall could be due to time limitations rather than collaborative inhibition. To ensure that the time we provided for recall is not the limiting factor, we analysed output at 2-minute intervals throughout the trial (including all output - instance repetitions, incorrect items and so forth).

Table 3 displays the mean output produced in each interval. We performed paired-sample  $t$ -tests for total items recalled in the first and last 2-minute intervals for Recall 1, Recall 2 and Recall 3. All tests demonstrated a significant reduction in output during the last 2-minute interval, in Recall 1: nominal,  $t(20) = 6.869$ ,  $p < .001$ ,  $d = 2.20$ , face-to-face,  $t(20) = 5.694$ ,  $p < .001$ ,  $d = 2.00$  and parallel CMC,  $t(20) = 9.046$ ,  $p < .001$ ,  $d = 2.75$ . In Recall 2: nominal,  $t(20) = 8.762$ ,  $p < .001$ ,  $d = 3.26$ , face-

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to-face,  $t(20) = 5.465$ ,  $p < .001$ ,  $d = 2.02$ , and parallel CMC,  $t(20) = 6.748$ ,  $p < .001$ ,  $d = 2.76$ . In Recall 3: nominal individual,  $t(62) = 14.254$ ,  $p < .001$ ,  $d = 2.82$ , face-to-face individual,  $t(62) = 7.671$ ,  $p < .001$ ,  $d = 1.78$  and parallel CMC individual,  $t(62) = 9.905$ ,  $p < .001$ ,  $d = 1.94$ . These findings demonstrate that available time per participant is not a limit on the number of words being recalled by the end of the recall period.

### **General Discussion**

Overall, our findings supported two out of our three main hypotheses. First, collaborative inhibition was present in semantic recall as nominal groups outperformed groups collaborating both face-to-face and via parallel CMC. This provides further evidence that collaborative inhibition can exist in semantic retrieval, supporting Hinds and Payne's (2016) findings. Further, collaborative inhibition was present in two successive recall trials (Recall 1 and Recall 2) and did not change over time.

Second, our findings demonstrated that individual semantic recall benefited from prior collaboration. Although it is not possible to establish whether final individual recall was a combination of episodic and semantic recall, the finding demonstrates that prior collaboration, although detrimental at the time, has longer-term benefits for retrieval. Third, parallel CMC did not appear to benefit collaborative recall. Although this contradicts previous findings where parallel CMC improved semantic recall (Hinds & Payne, 2016), it aligns with prior research on CMC and episodic recall, where CMC and face-to-face group recall were equivalent (Ekeocha & Brennan, 2008; Hinds & Payne, 2016). The equivalent levels of recall were reflected throughout the rest of the analyses, that is, neither collaborative condition was more effective in improving subsequent individual recall. However,

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similar to both Ekeocha and Brennan (2008) and Hinds and S. J. Payne (2016), the subsidiary analyses demonstrated that face-to-face and parallel CMC groups approached recall differently. The tendency for parallel CMC groups to generate more instance repetitions than face-to-face groups suggests that parallel CMC group members are able to partially attend to each others' contributions, which we suggest may enable them to utilise personal retrieval strategies (even though this did not result in improved retrieval overall). Similarly, the analyses for subjective organisation (clustering and paired frequency) enable us to distinguish between face-to-face and parallel CMC collaboration, where a more 'disorganised' group output in parallel CMC is reflects the ability for all group members to contribute simultaneously.

Taken together, these findings provide some interesting implications for numerous collaborative recall settings. There are many contexts where individuals move from or transition between collaborative and individual settings – educational and learning environments, in organisations and in social encounters. Further, within all of these settings the medium through which an individual communicates may change – face-to-face conversations may later be followed up via computer-mediated communication and vice versa. Although our findings demonstrated no difference between face-to-face and parallel CMC, our subsidiary analyses showed how group members approached recall differently in each condition. Further research could therefore examine how transitioning between different collaborative contexts and with different groups could impact individual semantic retrieval. For example, Choi et al (2014) found that in a similar recall constellation (CCI) when group membership changed in Recall 2, collaborative inhibition disappeared and subsequent individual recall was higher than individuals who remained in the same groups in prior collaboration. It is not necessarily the case that all prior collaboration benefits

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subsequent individual recall. Blumen and Rajaram (2008) found no improvement in recall when collaborative recall was followed by an individual recall (CII), therefore this may also extend to semantic retrieval.

Another suggestion for further research is to explore inhibitory effects in semantic recall over longer durations of time. In episodic recall, Takahasi and Saito (2004) found that collaborative inhibition disappeared when groups recalled a week after initial encoding. Given that semantic recall is supposed to be more enduring, this finding could have interesting implications for delayed group semantic recall and subsequent transfer to individual retrieval.

In summary, this research has challenged previous notions of collaborative inhibition in semantic recall. Computer-mediated communication changed the way that group members approached recall. More instance repetitions generated by parallel CMC groups demonstrated that group members partially attended to each other's contributions and lower clustering and paired frequency scores reinforced this finding. Despite the different approaches to retrieval, neither face-to-face nor parallel CMC proved to be more effective in collaboration or in supporting subsequent individual recall. Finally, prior collaboration did improve individual recall, demonstrating that collaborative inhibition in semantic recall is temporary.

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Table 1.

*Mean no. correct recall, instance repetitions and clustering scores for individual nominal face-to-face and parallel CMC groups and parallel CMC individuals in Recalls 1, 2 and 3.*

	Recall 1		Recall 2		Recall 3	
Condition	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Correct items						
Individual	40.29	17.94	47.76	23.31	53.31	23.77
Nominal	92.38	17.46	109.57	23.23	-	-
Face-to-face	65.67	17.75	79.81	20.08	64.02	17.78
Parallel CMC	70.52	23.46	89.23	26.98	61.05	21.61
Instance repetitions						
Nominal	29.52	9.58	37.05	10.94		
Face-to-face	1.29	1.49	4.43	3.93	2.77	2.71
Parallel CMC	12.69	9.11	21.92	13.43	3.08	3.13
Clustering						
Individual	0.44	0.25	0.56	0.23	0.60	0.18
Face-to-face	0.53	0.15	0.59	0.16	0.60	0.19
Parallel CMC	0.31	0.11	0.33	0.10	-	-
Parallel	0.29	0.24	0.39	0.23	0.58	0.20
Individuals						
No. categories recalled						

Individual	11.37	3.42	11.65	3.16	11.90	3.12
Face-to-face	13.24	2.41	14.10	3.05	13.60	3.04
Parallel CMC	14.85	2.56	15.95	2.65	-	-
Parallel individuals	9.04	2.82	10.56	4.18	14.14	2.63

Table 2.

*Mean hypermnesia scores for individual, nominal face-to-face and parallel CMC groups.*

Condition	Recall 1-2		Recall 2-3	
	M	SD	M	SD
Hypermnesia				
Individual	6.16	9.06	5.33	7.70
Nominal	16.67	12.99	-	-
Face-to-face	14.05	10.06	-	-
Parallel CMC	18.61	15.05	-	-

*Total mean output per 2-minute interval.*

[illegible]